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RECOMMENDED DIETARY ALLOWANCES

REVISED 1948

FOOD AND NUTRITION BOARD

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Revised 1948

Food and Nutrition Board, National Research Council

Historical Introduction

Dietary standards serve as a measure in planning diets and food supplies. Standards have existed for many years. They change from time to time as knowledge increases and no standard can be considered as final. The standards formulated by the League of Nations in 1935 were the result of a concerted group effort and were based on information then at hand. As research continued, numerous new standards were suggested by individuals and groups; these varied widely in completeness and in amounts of individual essentials. The range in recommended amounts was so great that a generally acceptable set of standards became impossible to develop by individual effort.

The Food and Nutrition Board was organized late in 1940 with the function of advising on problems of nutrition in connection with national defense. Immediately the need was recognized for standards on which some degree of general agreement could be expected. It was realized that requirements could not be established definitely on the basis of knowledge available, but it was desired to survey existing evidence and to derive a table of allowances that would represent, so far as possible, the combined judgment of nutrition authorities and thus be widely accepted and used. Standards previously proposed by various individuals and groups dealt almost exclusively with minimal requirements. It seemed preferable to the Board to formulate allowances suitable for maintenance of good nutritional status.

The published evidence concerning the requirements for the various dietary essentials was critically examined and appraised. In addition a large number of nutrition authorities, particularly those engaged actively in research, were asked for their judgments as to the requirements for any factors for which they had experimental or other basis for a decision. Tentative allowances were formulated from the evidence thus assembled. These suggested allowances were submitted to all contributors, as well as to all members of the Board, for criticism. The allowances were reformulated on the basis of the replies, resubmitted, and again revised. The values thus derived were adopted by the Board in May 1941, and were published as National Research Council Reprint and Circular Series No. 115, January 1943 (1). The values represented the combined judgment of more than fifty persons qualified to express an opinion. It is not to be implied that every contributor agreed fully with all the values adopted, but the contributors and the Board were willing to accept the values tentatively until standards derived from more extensive and exact research data could be obtained. The term "Recommended Allowances" rather

than "Standards" was adopted by the Board to avoid any implication of finality or of minimal or optimal requirements.

In 1942 the Allowances were extended by the addition of recommendations concerning iodine, copper, and vitamin K, but without change in any preceding recommendation.

In June 1944, when increasing evidence indicated that revision of the recommendations for the B group of vitamins had become desirable, a group of persons engaged actively in research in this field in the United States and Canada was brought together. This group reviewed the published evidence and exchanged personal views based on experimental data. Though diversity of opinion developed the divergence was within a range small enough that compromise values formulated by the committee were acceptable to most of the consultants, including several with extreme views. Similarly, the values were acceptable to the majority of the members of the Food and Nutrition Board. After mature consideration at several meetings of the Board, a second edition was adopted in June 1945 and published in August 1945.

Active work in preparation for the present (third or 1948) edition was begun early in 1947. Having already made full use of the method of debate, the committee in 1947 adopted a plan designed to ensure opportunity for thorough and deliberate study of every proposed change before bringing it to vote. To this end, each member of the committee was assigned (or made reporter for) the nutritional factor or factors with which he was deemed best qualified to deal. This (or these) he had opportunity to study for several months, after which he reported in writing to the committee as a whole, sketching the evidence up to date and proposing such changes, if any, as he considered should be made in the pamphlet on Recommended Allowances. Both his explanatory statement and his proposals for numerical changes were then distributed to all members of the committee for as many days of study as were needed and practicable before voting. At all times each member had entire freedom of conference with others whom he might desire to consult, whether members of the committee or not.

The Quantitative Level of the Recommendations

The general principle is followed here as previously of recommending allowances sufficiently liberal to be "suitable for maintenance of good nutritional status."

The quantitative data in the accompanying table are intended to represent exactly what is implied in a literal interpretation of the words *recommended dietary allowances*. Hence, in contrast to some previously promulgated standards, the data in the accompanying table are rather to be understood as representing levels of nutrient intakes which the Food and Nutrition Board recommends as normally desirable goals or objectives.

The recommendations are not called "requirements" because they are intended to represent not merely the literal (minimal) requirements of average individuals, but levels enough higher to cover substantially all individual variations in the requirements of normal people.

The figures here recommended are, therefore, generally higher than

average requirements but generally lower than the doses used to meet needs created by pathological states or certain environmental conditions or in compensating for an earlier period of depletion.

The Board recognizes a responsibility to explain as clearly as it can (even at the cost of some near-repetition) just how the levels of nutrient intake which it *recommends* are related to the lesser quantities which are essential to avoid manifest nutritional deficiencies. Studies on man, as well as more complete experience with animals, clearly indicate substantial improvements in growth and function when the intakes of certain nutrients are increased above the level which is just sufficient to prevent obvious deficiency symptoms. The level above which lesions or symptoms are not commonly observed is merely one point on a long curve relating intake to function. The allowance of a margin of intake above the critical level for each nutrient is, therefore, designed to permit additional benefits as well as to cover individual variations. No fixed formula for computing the margin between "minimal requirements" and "recommended allowances" would be equally logical for all nutrients or for all population groups. There is now much evidence from long-term animal experimentation that, aside from individual variations of need, the margins between optimal intake and minimal requirements are wider for some nutrients than for others. In the judgment of the Board substantially lower levels than those given in the accompanying table would not be expected to give equally good results with large numbers of people through long periods of time.

The experimental evidence relating the level of intake to biological performance is often different in kind for different individual nutrients. Hence further discussion of some questions of interpretation will be found among the subsequent notes on the individual nutrient factors.

Actual formulation of quantitative recommendations to express the preceding point of view is handicapped in several ways. For only some of the nutrients do we have agreement among investigators regarding methods of measuring minimal need. In only a few instances have there yet been sufficiently large numbers of measurements, by sufficiently satisfactory methods, to permit calculation of the statistical validity of a mean (average), or of the extent of normal variability from such "averages" as have come into general use. Furthermore, it is difficult to determine whether to average together findings obtained by different methods, perhaps not always equally accurate, or to use only the more easily interpretable data, with a corresponding risk of basing recommendations for whole populations upon measurements of only a very small sample of their members.

The following sections summarize briefly the foundational bases used in formulating the recommendations for each of the ten factors included in the table.

As indicated previously, the nutrient factors differ in respect to desirability of surplus intake. The usual undiscriminating view is that, if the diet furnishes enough of any given factor to meet functional need, any further amount supplied by the food is normally a matter very nearly of indifference, significant only as a sort of insurance against some emergency. This may be true for most of the essential food factors. Of a few nutrients, however, there is evidence from long-term (animal) experimentation that

one may, in the course of a lifetime, derive increased benefit from increased intake up to levels very considerably above those of ordinarily accepted adequacy. (Ascorbic acid, vitamin A, and calcium are perhaps the best-established cases of this kind.) Conversely, it may be true of some other nutrient factors that surplus intakes should be held within bounds if undesirable consequences are to be avoided. The outstanding and undisputed example of the latter is the energy value or calories of the diet, of which any considerable surplus intake tends to induce overweight.

Calories. The proper calorie allowance is that which over an extended period will maintain the body weight (or rate of growth) at the level most conducive to well-being. Due account should be taken of the concept of "ideal weight" as developed through the study of life insurance experience.[1] Height, age, sex, and environmental and genetic factors must also be taken into consideration. Obviously, single values cannot be equally accurate for different individuals whose needs are influenced by so many circumstances. Hence it is suggested that the recommended calorie allowances be regarded as subject to modifications of plus or minus 15 to 20 percent according to conditions.

The present revisions of the calorie allowances for the activity categories of normal adults involve 1) the downward revision of amounts allowed for sedentary men and sedentary and moderately active women; 2) upgrading of the degree of activity for the second and third categories of men to *physically active* and *with heavy work*, respectively. Undoubtedly "physically active" implies greater muscular activity than the former term "moderately active"; and "with heavy work" implies more than "very active." These changes therefore may help to emphasize the differences existing among the occupations of men but not among the occupations of women (at least in the countries in which this publication will be chiefly used). More adequate recognition of the differences of calorie needs among men according to their activities is in line with recommendations of the Committee on Nutrition of Industrial Workers.

As to the most desirable levels of calorie intake during pregnancy and lactation, the allowances recommended in the table seek a middle ground within the somewhat broad range of present professional opinion.

Commonly accepted energy requirements for infants are 120 Calories/kilogram in early infancy, falling to 110 Calories at six months, and 100 at one year. In accordance with this, the recommendation in the table is for 110 Calories/kilogram at the midpoint of the first year of age.

Inasmuch as research in the intervening years tends to confirm rather than to modify the allowances for children over one year of age as given in the 1945 revision, these allowances have not been changed. These values were based on a compilation of the studies in the literature (2) of the values of food consumed and on a preliminary analysis of unpublished studies by Roberts and Blair of several hundred children. The original value of 2800 Calories for girls 13 to 15 years of age was reduced to 2600 Calories in the 1945 revision. At all age levels the allowance should vary in relation to

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[1] It is reported that the tables summarizing the experience of the life insurance companies and the studies of the Public Health Service are now (1948) being revised.

size and activity. The greatest variation occurs in adolescence. A large, active boy of 15 years may need as much as 5000 Calories. In most instances appetite may be depended on for satisfaction of the need when food is available. A deficit is reflected in loss of weight or, in the case of children, by failure to make the normal gain. Even when calorie allowances are used for planning for specific groups, they can be only rough guides.

Protein. The protein allowances recommended for normal adults (regardless of muscular activity but not including pregnancy or lactation) are based on the standard of one gram of protein per day for each kilogram of body weight. This value or level has been widely used as a standard that provides a reasonable margin of safety. Its original basis (3) was the average amount required for equilibrium in more than one hundred nitrogen-balance experiments in the course of twenty-five independent investigations including work in several countries and with both sexes, which average was increased by fifty percent to cover both individual differences in need and variations in the nutritive efficiency of the protein of different diets. The maintenance allowances thus arrived at by the Board in 1941 and reaffirmed in 1945 are again reaffirmed in 1948. Recent important advances in scientific knowledge of the chemistry and physiology of the proteins may contribute to a basis for more discriminating use of protein in the medical practice of the future. The recent extensive research of Hegsted, Tsongas, Abbott, and Stare (4) indicates that the present allowance carries generous provision for differences in the proteins of normal diets as well as for individual variations of protein requirement among normal people.

The protein allowances for pregnancy and lactation are based on the observations of Macy and her coworkers (5), Coons (6), and others. These investigators showed that growth of the fetus and adnexa in pregnancy and the demands for milk production in lactation greatly increase the protein needs over those of the nonpregnant state. The increased need begins in the latter half of pregnancy and is greatest when lactation has reached its maximum. The values in the table represent relative needs rather than accurate requirements, for the requirement varies with size.

The protein allowances for children were derived from a compilation of balance studies of children of all ages, as found in the literature. These data indicate that the intakes of protein per kilogram with which appropriate positive balances are obtained decrease from 4 to 3.5 gm. in infancy, from 3 to 2.5 gm. in early childhood, from 2 to 1.5 gm. in late childhood and adolescence, to the adult maintenance standard of 1 gm. The amounts in the table represent approximately these values. The amounts actually required vary with the size of the child and with the quality of the protein. An infant fed human milk may thrive with an intake much lower than the recommended allowances.

Calcium. The calcium allowance for normal adults (except during pregnancy and lactation) in the 1945 recommendations was based predominantly upon the calcium-balance experiments of Steggerda and Mitchell (7) and of Outhouse and coworkers (8). These investigators found that 11 of 16 subjects gave results indicating that 10 mg. of calcium

per kilogram of body weight would suffice for equilibrium, while the remaining 5 subjects would require somewhat more. Using the 10 mg. per kg. value, a 70 kg. average man would need 0.7 gm. It was thought at that time that a recommended allowance of 0.8 gm. would represent a sufficient margin for individual variability and that this might also be regarded as approximating closely the indications of the data compiled in 1937 by Leitch (9). Many new data (10) have been published since that time. In parallel with the study of this new evidence, a reexamination has also been made of all the evidence available to the beginning of 1948 from the viewpoint of the validity of each individual balance experiment in the light of present knowledge. The 73 cases which from this reexamination appeared most clearly valid give a much broader basis than existed in 1945 for making an adequate allowance for individual variability of need. In the light of all the evidence now available the recommended allowance of calcium for normal maintenance is here set at 1.0 gm. per day. Statistically this covers the needs of all but about one in one hundred of the normal adult population. The extended investigations of Leverton and Marsh (11), and of McKay, Patton, *et al.* (12) covering altogether about 150 studies made on what may be designated as a somewhat more observational plan than that of the 73 cases above mentioned, likewise led to the recommendation of 1.0 gm., as did also the more recent work of Roberts, Kerr, and Ohlson (13). The evidence supports the conclusion that, while people can adjust themselves to less, they are then not so well off in the long run. This conclusion is confirmed by large numbers of long-time experiments with laboratory animals (14). The same maintenance allowance is recommended for women as for men, despite their smaller average size, in order to insure ample stores in preparation for maternity. The higher allowances for pregnancy and lactation are intended to provide for the growth of the fetus with placenta, etc., and for milk production. These increased needs are indicated by the observations of Macy and coworkers, Coons, and others (15).

In arriving at the calcium allowances for children, special consideration was given to the studies by Daniels (16) and by Outhouse (17) of preschool children, and by Wang (18) of adolescent girls. The earlier studies by Sherman and Hawley (19) and by Wang and coworkers (20) were also evaluated, as were the calculations made by Leitch (9) as to the probable requirements during the period of growth. In a study of 10 preschool children Outhouse found as good retention with an intake of 615 mg. as with a larger amount. This result is in accord with those of Daniels and of Wang and with Sherman and Hawley's early findings in a study of two preschool children. This amount appears sufficient provided the stores are approximately saturated and the diet is otherwise adequate. Because of the relatively small number of children and the short duration of the studies, a margin of safety seemed desirable and an allowance of 1 gm. was recommended.

Beyond the preschool period, data on which to base requirements were meager. The allowances were largely derived from the calculations of Leitch, from balance studies of Wang for adolescent girls, and from Sherman and Hawley's (19) study of one 12-year-old girl. These studies and

calculations indicate that the calcium needs increase through the growth period to well above the 1 gm. level and then decline to that of the adult. With three points established in the manner described—the preschool child, the adolescent girl, and the adult—the values for other ages were interpolated to correspond to the curve of normal growth. Undernourished children may require special treatment.

Since the allowances were first proposed, Macy (21) has reported results of long-time balance studies of 21 children 5 to 12 years of age. With intakes closely approximating the dietary allowances, these children had good calcium retentions. The results of this comprehensive study thus support the recommended allowances for children.

Phosphorus. In the original table no allowances were formulated for phosphorus, largely because of the view that dietary deficiencies of phosphorus are uncommon and that diets which are adequate in other respects, particularly in calcium, are ordinarily adequate in phosphorus. For the purpose of making the 1945 revision, a large amount of published and unpublished data from balance studies was brought together and the data evaluated. The footnote which has been added to the table of allowances expresses the result with sufficient accuracy so that a separate column in the table does not seem indicated. When the calories are obtained largely from cereal, computation of the total phosphorus intake may be misleading because phytin phosphorus may be utilized poorly unless the supply of vitamin D is adequate. The requirement for phosphorus cannot be considered alone, but must be related to the intake of calcium and protein. Furthermore, the utilization of phosphorus, like that of calcium, varies with the amount of vitamin D.

Iron. The recommended allowances for iron were based to a large extent on the suggestion of Sherman (22) that 12 mg. is a desirable level of intake for adults. The mean intake of 8 mg. required by his subjects for equilibrium was increased by 50 percent to attain a standard allowing a margin of safety. There is considerable evidence, especially the observations of McCance and Widdowson (23), of Hahn (24), and of others, that adult males can be maintained for short periods of time with very low intakes of iron. However, the 12 mg. level has been retained for the following reasons: Iron deficiencies have been reported in certain population groups; a generous intake may be desirable for other reasons; this level can be attained with little difficulty through the use of otherwise satisfactory diets. Experiments have indicated that iron is absorbed largely in response to a need, as in growth or after loss of blood.

Leverton (25) showed that young women were in equilibrium with an intake of approximately 7 mg. daily. In a later study (26) she found a larger amount to be needed unless the diet contains all other dietary essentials abundantly. When these amounts are increased by 50 percent to give a margin of safety, the recommended allowance of 12 mg. for women becomes justified, for iron like calcium is poorly utilized by many persons.

The demands of pregnancy have been estimated (27) to require an increase of about 3 mg. over the normal requirement. Therefore this amount was added to the 12 mg. allowance assigned to the non-pregnant woman. McCance and Widdowson found good hemoglobin levels in

pregnant women with this intake. Although no evidence exists that the need for iron is materially increased in lactation, since milk contains little, it seemed wise to retain the same allowance during lactation as for pregnancy.

Studies of the iron requirement for children have been reported for infancy and the preschool years only. Stearns and Stinger (28) and Oldham, Schlutz, and Morse (29) showed that for infants 0.5 mg. for each kilogram is close to the minimum needed to maintain a positive balance and a good hemoglobin level. From a critical appraisal of the results of Rose (30), Leichsenring and Flor (31), Ascham (32), Daniels (33), and Porter (34) in studies of preschool children it was concluded that the need can be met by 0.3 to 0.4 mg. for each kilogram. The allowances for the preschool years were obtained by using these values in relation to the weights at the different ages. For the child of early school age, 7 to 11 years, the allowances recommended are supported by the observations of Johnston (35), who found that children of these ages could maintain normal hemoglobin levels with an intake of 0.35 mg. for each kilogram, or a daily total of 9 to 10 mg.; larger amounts caused no improvement.

Darby and coworkers (36) studied the iron absorption with radio-active Fe^{59} in school children 7 to 10 years of age. The iron intakes, estimated from diet records, averaged about 12 mg. daily. The hemoglobin levels appeared normal for the age. When two or three mg. doses of iron containing the tracer were fed, from 10 to 16 percent of the iron reappeared in the circulating red cells. Such a high percentage absorption in adults would be taken to mean an iron deficiency. Although the adequate hemoglobin values argue against this interpretation, it would appear that children absorb more iron than would have been expected from their estimated absolute needs for growth increments (.3 to .5 mg. per day); hence daily allowance of 10 mg. does not seem excessive.

No data are available for the requirement during adolescence. The allowances recommended were estimated on the assumption that needs are greater than those of the adult.

Vitamin A Value. The content of vitamin A itself and of its precursor carotene(s) together account for the vitamin A value of a dietary. The carotenes of different foods, however, yield varying proportions of their theoretical vitamin A values to the body. Booher and coworkers (37, 38) found that human beings require an average of 73 percent (61 to 84 percent) more of pure beta-carotene dissolved in oil than of pre-formed vitamin A (cod liver oil) when measured in International Units, to maintain normal dark adaptation after the depletion of bodily stores of vitamin A (5 subjects). Apparently the human being uses beta-carotene in oil less completely than does the rat.

Also Callison and Keiles (39) working with beta-carotene in oil, peas, spinach, and carrots found that human subjects utilize carotene from these sources to varying degrees. To maintain normal dark adaptation human beings when given carotene in the form of cooked garden peas required only 62 percent as much (in mcg. of beta-carotene) as when given the pure substance in oil; when given cooked spinach, only 82 percent as much;

and when given cooked carrots, at least 143 percent more than when given the pure substance in oil.

The rat, as well as the human, appears to utilize carotene more effectively from some foods than from others. Unpublished data from the laboratories of the Bureau of Human Nutrition and Home Economics indicate that the rat utilizes about two-thirds of the carotene present in cooked kale but only about one-third of the carotene present in cooked carrots.

Obviously, chemical studies of the carotene content of foods are not an adequate measure of their relative vitamin A values—either to the human or to the rat. Further work is needed on the comparative biological value of carotene in foods. Until such work is completed it is impossible properly to relate data on food requirements and on food composition. Moreover, there is divergence among different experimental methods of studying this requirement, further complicated by the capacity of the body for storage. Most of the estimations of the human requirement in the literature are based on studies of the amount needed to maintain normal dark adaptation of the eye.

The allowance of 5000 I.U. for adults was based largely on the studies of Booher (37), Blanchard (40), and Guilbert (41) and on the critical evaluation of the literature by With (42). These studies indicated that the requirement is 25 to 55 units for each kilogram, or 2000 to 4000 units of vitamin A per se daily for the adult, and twice these amounts or more if the sole source is carotene from foods. Approximately two-thirds of the vitamin A value of the average diet as now calculated in the U. S. is contributed by carotene. In deriving the vitamin A values used in these calculations, both chemical and biological values, where they existed, were considered. Biological values represent utilization by the animal body; this means that some allowance for the factor of utilization is inherent in the calculations. It was decided, therefore, that 5000 units as calculated from current tables would represent a fair over-all allowance when consumption of foods follows the pattern of the U. S. national food supply.

Because few studies indicating requirements have been made with children, the allowances for children were formulated on the basis of the judgment of the referees and on calculations based on weight. It is generally agreed that the vitamin A requirement is related to body weight rather than to energy expenditure. If the requirements for children are computed according to weight on the basis of Booher's highest estimate of the need of the adult, the values for boys, for example, would be 550 units at one year; 1000 at 4; 1430 at 8; 2200 at 12; and 3300 at 16 years. If we assume that the requirements are relatively higher on the basis of weight, as in the case of protein and the minerals, and multiply these values by appropriate factors (for example, those from protein, as 3, 2.5, 2, 1.5), values approximating the recommended allowances are obtained. Amounts in excess of these recommended allowances are easily obtained in diets containing desirable amounts of milk, eggs, and green vegetables.

Since the adoption of the 1945 table of recommended allowances, a preliminary report of experiments upon human adults by Coward, *et al.* (43) has appeared which suggests the possibility of downward revision. On the

other hand, an upward revision of the 1945 allowances is suggested by the animal experimentation at Columbia University in which large numbers of full-life and successive-generation experiments showed that better long-run results were induced by increases of vitamin A intake to levels relatively higher than those of the recommended allowances of 1945 (44).

Inasmuch as there are these recent trends in both directions and further research bearing upon the problem is being carried on, it is deemed best to make no changes in the recommended allowances of vitamin A value at present.

Thiamine. The values of the 1945 revision were based on reports in the literature together with the results of a conference between persons actively engaged in thiamine research. For the purpose of arriving at the present recommended allowances the literature, including reports since 1945, has again been reviewed.

For practical purposes it seems best to continue to consider the thiamine requirement in terms of total calories of the diet. In the original table the thiamine allowances for the several categories were based on the concept that a definite ratio exists between calories and thiamine throughout the entire calorie range. The chief changes in the 1945 revision were based on the consensus that the proportion of thiamine required decreases as the caloric expenditure increases above the basal levels. This concept is retained.

Several studies of adults (45) indicate that the minimum thiamine requirement is 0.23 mg. or less for each 1000 Calories. In other reports the authors interpret their results as indicating a higher requirement. Elsom and coworkers (46) state the minimum requirement as 0.35 mg. for each 1000 Calories. Williams and coworkers (47) place the minimum requirement at approximately 0.45 mg. for each 1000 Calories. In a critical analysis of the two preceding reports, Holt (48) reinterpreted the data as showing a minimum requirement of something more than 0.17 mg. for each 1000 Calories in one case and barely in excess of 0.22 in the other.

Oldham and coworkers (49) found increasing urinary excretion with increasing intakes and concluded that 0.5 mg. for each 1000 Calories is none too much. However, the data show no essential difference in the amount of thiamine in the blood with intakes of 0.2, 0.36, and 0.51 mg. for each 1000 Calories. The larger excretion with the larger intake could be interpreted as representing excessive intake.

Hathaway and Strom (50) found good urinary excretion with an intake of 0.37 mg. for each 1000 Calories; smaller amounts were not tried. Melnick (51) found that an intake of 0.35 mg. for each 1000 Calories resulted in excretions indicative of adequate tissue stores. Foltz and coworkers (52) obtained approximately the same results as Melnick. Glickman and coworkers (53) found an intake of 0.4 mg. for each 1000 Calories fully adequate.

On the basis of the evidence reviewed, including diet studies of population groups, the minimal requirement for adults may be stated as 0.23 mg. or more for each 1000 Calories. It is recognized that requirements vary with different persons and with the type of diet. Some diets are higher than average in carbohydrate. The recommended allowance must be

high enough to meet the high as well as the low requirements. Thiamine is one of the several nutrients of which the body stores are never large and are exhausted early by febrile and other diseases, by surgical operation, and by other stresses. Inasmuch as normal persons at any time may be forced to meet such stresses, it is desirable that stores of thiamine be maintained. In view of these considerations it was decided to provide as a factor of safety an allowance of thiamine approximately 100 percent more than the lower reported minimum requirements. The value of 0.5 mg. for each 1000 Calories was accepted as a safe allowance for adults at ordinary low levels of calorie intake. If the calorie intake is drastically reduced, the thiamine intake of the adult should not fall below 1 mg. daily. For very active persons whose energy requirement exceeds 3000 Calories, the thiamine allowance should be increased 0.2 mg. instead of 0.5 mg. for each additional 1000 Calories above the 3000 Calorie level.

The thiamine requirement of the infant has been studied chiefly in relation to the thiamine content of human milk. Various such studies have been made; the most extensive have been those of Knott and coworkers (54). These authors suggest 30 micrograms for each kilogram as the minimum requirement. At six months of age this amount would be equivalent to 0.27 mg. for each 1000 Calories. However, the average content of human milk is 0.15 mg. to the liter or 0.22 mg. for each 1000 Calories. No evidence of deficiency has been reported at this level or at levels somewhat lower. Similarly the average whole milk dilution formula for infants does not contain more than 0.24 mg. for each 1000 Calories; because of the heat treatment it receives it may be less by 20 percent or more. Babies receiving such formulas do not show evidence of deficiency. Thus it appears that the minimum requirement for the infant in relation to calories is very similar to that of the adult. It is reasonable that the same proportional allowance should be appropriate.

No report satisfactory for assessing the requirement of children has been found. Because infants and adults have the same minimum requirement in relation to calories, it is assumed that these same values apply also to the various ages in childhood.

Few data have been found relating to the requirement during pregnancy. Oldham and coworkers (55) studied women during the last five months of pregnancy. With an intake of 1.0 mg. the urinary excretion was 200 micrograms, indicating that this amount is ample and that the thiamine requirement in pregnancy has the same proportion to calories as in other categories. On the other hand, Toverud (55*a*) reports that in Norway during the war period, when the population was regimented as to diet, pregnant and non-pregnant women had much the same diet except that 750 cc. of milk was allotted to pregnant women. The non-pregnant women studied had small excretions of thiamine, whereas pregnant women had little or none and in many instances developed symptoms of thiamine deficiency. These findings suggest a requirement for thiamine during pregnancy greater than that proportionate to calorie intake in other categories.

The requirement during lactation has been studied by Macy and coworkers (55*b*). In one study 1.23 mg. was found adequate. The mothers

maintained weight, the milk was of good quality, and the infants thrived. In a subsequent study 1.1 mg. daily was found to be adequate. These values correspond to those reported for other categories. The allowances recommend the same margin of safety as for other groups.

Riboflavin. Evidence for assessing the desirable allowance of riboflavin is still rather incomplete. With man, as with experimental animals, deficiency symptoms are slow to develop after riboflavin deprivation. Sebrell and Butler (56) found, even with markedly restricted diets, and with subjects who were not very well nourished initially, that three to five months were required before the appearance of demonstrable lesions. It seems likely that very long experimental periods would be required before the consequences of milder deficiency states would become evident.

Certain aspects of riboflavin nutrition, however, seem to have been clarified by accumulated evidence. There appears to be little justification for providing a higher riboflavin allowance for very active persons than for sedentary ones. In the previous allowance table it had been assumed that the destruction of riboflavin, like that of thiamine, increases as the caloric consumption increases. There is clear evidence from experiments with rats that this is not the case, nor does a change in the metabolic mixture affect the requirement except as it may affect the intestinal synthesis of riboflavin (57). Keys, *et al.* (58) observed no physical or functional deterioration in a group of active young men who for nearly six months were supplied with only 0.29 mg. riboflavin per 1000 Calories; whereas Sebrell, Butler, and Wooley (59) found that in three to eight months a group of sedentary women receiving 0.21 mg. riboflavin per 1000 Calories developed distinctive physical signs of deficiency, which were responsive to riboflavin therapy. These data are understandable if it is realized that the young men, because of their greater food consumption, received a total of nearly 1 mg. of riboflavin daily whereas the sedentary women ingested but 0.5 mg. per day. It would appear desirable to base the riboflavin allowance, not on the caloric consumption, but rather on the body weight or possibly on some function thereof. In the (1948) revised table the same riboflavin allowance is recommended for active and for sedentary persons.

The subjects of the study of Sebrell, *et al.* (59) mentioned above, who developed signs of deficiency, received in their diet 9 micrograms of riboflavin per kilogram of body weight per day. Williams, *et al.* (60) found no apparent handicap in four female subjects maintained for nine months on 13 micrograms of riboflavin per kilogram per day. However, neither 13 nor 17 micrograms per kilogram prevented a certain degree of depletion of tissue riboflavin as measured by load tests. Davis, Oldham, and Roberts (61), in a study of nine previously well nourished women, found that 10 micrograms of riboflavin per kilogram per day prevented any apparent deterioration for at least three and a half months, but that between 18 and 21 micrograms per kilogram were required daily to prevent tissue depletion as assessed by load tests. Keys and others (58), using a battery of psychological and functional tests, found no handicap to four active young men who subsisted for five and a half months on 15 micrograms of riboflavin per kilogram per day. These experimenters also found that a depletion of tissue riboflavin resulted from this level of supply as shown by the failure

of the experimental subjects to excrete as much riboflavin as control subjects when given a more generous riboflavin intake. The urinary deficit persisted for several weeks.

In the absence of prolonged human studies, it seems desirable to aim at riboflavin allowances which will prevent tissue depletion. The preceding studies suggest that this would require approximately 20 micrograms per kilogram per day, or 1.1 and 1.4 mg. per day respectively for a 56 kilogram woman and a 70 kilogram man. Because of the limited nature of the evidence from human subjects and the numerous findings in animal experimentation (62) that best long-run results (in lifetimes and successive generations) require very considerably larger amounts of riboflavin than those which meet "requirements" in the sense of experiments covering only a small fraction of a natural lifetime, the allowances for the 70 kilogram man and 56 kilogram woman have been set at 1.8 and 1.5 mg. regardless of activity.

The allowances for pregnancy and lactation have not been altered in view of the desirability of high standards during these stress periods. During gestation riboflavin is required not only for the developing fetus, but for the placenta, uterus, and quite probably other tissues as well. The special need for riboflavin during lactation is selfevident.

There are few observations on the riboflavin requirements of children. Oldham, *et al.* (63) concluded that in the case of two five-year-old boys studied, 30 micrograms of riboflavin per kilogram per day were probably sufficient to prevent tissue depletion. L. E. Holt, Jr. and coworkers (personal communication) have found, for children under three years, that increasing the riboflavin intake to about 450 micrograms per day (18 to 36 micrograms per kilogram) resulted in a rather sharp increase in urinary excretion of the vitamin. The requirement did not appear to increase directly with the body weight. The allowances in the table for children under 12 years provide about 60 micrograms riboflavin per kilogram. This amount seems generous, but a lower allowance is felt unwarranted in view of the limited character of present studies and of the implication of these studies that children require somewhat more riboflavin per kilogram than adults.

Niacin (Nicotinic Acid). At the time the original table of allowances was formulated, no human experiments on which to base an estimate of requirement were on record. The recommended values were based largely on calculations from the requirements of dogs as found by Elvehjem and on the checking of these calculated values against diets known to be adequate for the prevention of pellagra. When the allowances were thus calculated for the different ages, it was found that they were approximately 10 times the thiamine allowances. This observation gave support to the computed values in that the requirement of these two nutrients might be expected to bear a constant relationship to each other because they, together with riboflavin, play a part in the oxidation reduction systems of the body through which the energy of food is released. At the time of the 1945 revision, evidence as to the niacin requirement was still less adequate than for many of the other factors and it was decided to retain the ten-to-one relationship to thiamine.

RECOMMENDED DAILY DIETARY ALLOWANCES[1]

REVISED 1948

Food and Nutrition Board, National Research Council

	Calories[2]	Protein, gm.	Calcium, gm.	Iron, mg.	Vitamin A,[3] I.U.	Thiamine,[4] mg.	Riboflavin,[4] mg.	Niacin (Nicotinic acid),[4] mg.	Ascorbic acid, mg.	Vitamin D, I.U.
Man (154 lb., 70 kg.)										
Sedentary	2400	70	1.0	12[5]	5000	1.2	1.8	12	75	[6]
Physically active	3000	70	1.0	12[5]	5000	1.5	1.8	15	75	[6]
With heavy work	4500	70	1.0	12[5]	5000	1.8	1.8	18	75	[6]
Woman (123 lb., 56 kg.)										
Sedentary	2000	60	1.0	12	5000	1.0	1.5	10	70	[6]
Moderately active	2400	60	1.0	12	5000	1.2	1.5	12	70	[6]
Very active	3000	60	1.0	12	5000	1.5	1.5	15	70	[6]
Pregnancy (latter half)	2400[7]	85	1.5	15	6000	1.5	2.5	15	100	400
Lactation	3000	100	2.0	15	8000	1.5	3.0	15	150	400
Children up to 12 yrs.[8]										
Under 1 yr.[9]	110/2.2 lb. (1 kg.)	3.5/2.2 lb. (1 kg.)	1.0	6	1500	0.4	0.6	4	30	400
1–3 yrs. (27 lb., 12 kg.)	1200	40	1.0	7	2000	0.6	0.9	6	35	400
4–6 yrs. (42 lb., 19 kg.)	1600	50	1.0	8	2500	0.8	1.2	8	50	400
7–9 yrs. (58 lb., 26 kg.)	2000	60	1.0	10	3500	1.0	1.5	10	60	400
10–12 yrs. (78 lb., 35 kg.)	2500	70	1.2	12	4500	1.2	1.8	12	75	400
Children over 12 yrs.[8]										
Girls, 13–15 yrs. (108 lb., 49 kg.)	2600	80	1.3	15	5000	1.3	2.0	13	80	400
16–20 yrs. (122 lb., 55 kg.)	2400	75	1.0	15	5000	1.2	1.8	12	80	400
Boys, 13–15 yrs. (108 lb., 49 kg.)	3200	85	1.4	15	5000	1.5	2.0	15	90	400
16–20 yrs. (141 lb., 64 kg.)	3800	100	1.4	15	6000	1.7	2.5	17	100	400

[1] Objectives toward which to aim in planning practical dietaries: The recommended allowances can be attained with a good variety of common foods which will also provide other minerals and vitamins for which requirements are less well known.

[2] Calorie allowances must be adjusted up or down to meet specific needs. The calorie values in the table are therefore not applicable to all individuals but rather represent group averages. The proper calorie allowance is that which over an extended period will maintain body weight or rate of growth at the level most conducive to well-being.

[3] The allowance depends on the relative amounts of vitamin A and carotene. The allowances of the table are based on the premise that approximately two-thirds of the vitamin A value of the average diet in this country is contributed by carotene and that carotene has half or less than half the value of vitamin A.

[4] For adults (except pregnant and lactating women) receiving diets supplying 2000 calories or less, such as reducing diets, the allowances of thiamine and niacin may be 1 mg. and 10 mg. respectively. The fact that figures are given for different calorie levels for thiamine and niacin does not imply that we can estimate the requirement of these factors within 500 calories, but they are added merely for simplicity of calculation. In the present revision, riboflavin allowances are based on body weight rather than caloric levels. Other members of the B complex also are required, though no values can be given.

Foods supplying adequate thiamine, riboflavin, and niacin will tend to supply sufficient of the remaining B vitamins.

[5] There is evidence that the male adult needs relatively little iron. The need will usually be provided for if the diet is satisfactory in other respects.

[6] The need for supplemental vitamin D by vigorous adults leading a normal life seems to be minimum. For persons working at night and for nuns and others whose habits shield them from the sunlight, as well as for elderly persons, the ingestion of small amounts of vitamin D is desirable.

[7] During the latter part of pregnancy the calorie allowance should increase to approximately 20 percent above the preceding level. The value of 2400 calories represents the allowance for pregnant, sedentary women.

[8] Allowances for children are based on the needs for the middle year in each group (as 2, 5, 8, etc.) and are for moderate activity and for average weight at the middle year of the age group.

[9] Needs for infants increase from month to month with size and activity. The amounts given are for approximately 6 to 8 months. The dietary requirements for some of the nutrients such as protein and calcium are less if derived largely from human milk.

Further recommendations:

Fat. There is available little information concerning the human requirement for fat. Fat allowances must be based at present more on food habits than on physiological requirements. While a requirement for certain unsaturated fatty acids (the linoleic and arachidonic acids of natural fats) has been amply demonstrated with experimental animals, the human needs for these fatty acids is not known. In spite of the paucity of information on this subject there are several factors which make it desirable (1) that fat be included in the diet to the extent of at least 20 to 25 percent of the total calories and (2) that the fat intake include essential unsaturated fatty acids to the extent of at least 1 percent of the total calories. At higher levels of energy expenditure, e.g., for a very active person consuming 4500 calories and for children and for adolescent persons, it is desirable that 30 to 35 percent of the total calories be derived from fat. Since foodstuffs such as meat, milk, cheese, nuts, etc., contribute fat to the diet, it is necessary to use separated or "visible" fats such as butter, oleomargarine, lard, or shortenings to supply only one-third to one-half the amounts indicated.

Water. A suitable allowance of water for adults is 2.5 liters daily in most instances. An ordinary standard for diverse persons is one milliliter for each calorie of food. Most of this quantity is contained in prepared foods. At work or in hot weather, requirements may reach 5 to 13 liters daily. Water should be allowed *ad libitum*, since sensations of thirst usually serve as adequate guides to intake except for infants and sick persons.

Salt. The needs for salt and for water are closely interrelated. A liberal allowance of sodium chloride for the adult is 5 grams daily, except for some persons who sweat profusely. The average normal intake of salt is 10 to 15 grams daily, an amount which meets the salt requirements for a water intake up to 4 liters daily. When sweating is excessive, one additional gram of salt should be consumed for each liter of water in excess of 4 liters daily. With heavy work or in hot climates 20 to 30 grams daily may be consumed with meals and in drinking water. Even then, most persons do not need more salt than usually occurs in prepared foods. It has been shown that after acclimatization persons produce sweat that contains only about 0.5 gram to the liter in contrast with a content of 2 to 3 grams for sweat of the unacclimatized person. Consequently after acclimatization, need for increase of salt beyond that of ordinary food disappears.

Iodine. The requirement for iodine is small, probably about 0.002 to 0.004 mg. daily for each kilogram of body weight, or a total of 0.15 to 0.30 mg. daily for the adult. This need is met by the regular use of iodized salt; its use is especially important in *adolescence* and *pregnancy*.

Phosphorus. Available evidence indicates that the phosphorus allowances should be at least equal to those for calcium in the diets of children and of women during the latter part of pregnancy and during lactation. In the case of other adults the phosphorus allowances should be approximately 1.5 times those for calcium. In general it is safe to assume that if the calcium and protein needs are met through common foods, the phosphorus requirement also will be covered, because the common foods richest in calcium and protein are also the best sources of phosphorus.

Copper. The requirement for copper for adults is about 1 to 2 mg. daily. Infants and children require approximately 0.05 mg. for each kilogram of body weight. The requirement for copper is approximately one-tenth that for iron. A good diet normally will supply sufficient copper.

Vitamin K. The requirement for vitamin K usually is satisfied by any good diet except for the infant in utero and for the first few days after birth. Supplemental vitamin K is recommended during the last month of pregnancy. When it has not been given in this manner, it is recommended for the mother preceding delivery or for the baby immediately after birth.

Folic Acid. Evidence for recognizing folic acid (pteroylglutamic acid, vitamin B_c, L. casei factor or vitamin M) as an essential human nutrient is presented in the text. The quantitative requirement cannot be closely estimated from evidence now available.

In 1946 Frazier and Friedemann (64) recalculated, on the basis of recently published data, the protein, thiamine, riboflavin, and niacin content of pellagra-producing and pellagra-preventing diets and concluded that the minimum daily intake of niacin in a marginal diet containing corn products is about 7.5 mg. per day. These authors also pointed out that the milk diets used by Goldberger for the prevention of pellagra supplied about 5 mg. per day. Recent work has established that part of the niacin requirement can be supplied by dietary tryptophane through bacterial synthesis in the intestinal tract or through internal metabolic processes. Ellinger and Benesch (65) have studied the urinary elimination of the end products of niacin metabolism, especially N′-methylnicotinamide, in human subjects and have found that succinyl sulfathiazole, which is known to alter the intestinal flora, produces a significant decrease in the amount excreted. Denko, *et al.* (66) have measured the excretion of several B vitamins by normal adults on a restricted intake and found that the total excretion of niacin in the urine and feces was approximately equal to the intake but did not show the large excess observed in the case of biotin and folic acid. Benesch (67) has also demonstrated that anaerobic organisms may actually destroy niacin produced by aerobic organisms. Thus, there may be sufficient synthesis to alter the total requirement but not sufficient to rely upon to any great extent.

In the rat, niacin is an essential nutrient only when the tryptophane content of the diet is low (68, 69). Under these conditions (70) the niacin requirement is approximately 10 times the thiamine need. The high incidence of pellagra when the human diet is rich in corn and low in animal protein is undoubtedly due not only to the low amount of niacin in corn, but to the fact that the main corn protein, zein, is very low in tryptophane. There is good evidence (71, 72) that tryptophane may function as a precursor of niacin and therefore the actual niacin requirements can be established only in relation to the protein intake. Until the amino acid content of all diets is more accurately established, any marked change in the present niacin allowance would be unwise. However, no difficulty should be encountered from lower intakes of niacin if an adequate level of good quality protein is included.

The requirement for infants and children has been retained at the higher level although it is recognized that a diet consisting largely of milk will not meet this requirement directly. Although the diet may not supply 4 mg. of preformed niacin, this amount is undoubtedly available to the body because milk is a good source of tryptophane and because milk actually favors the intestinal synthesis of niacin. It is important to emphasize that the growing child needs both tryptophane and niacin for the production of new tissue.

Folic Acid. The evidence in support of accepting folic acid (pteroylglutamic acid, vitamin B_c, *L. casei* factor, or vitamin M) as an essential human nutrient rests primarily on the following types of observation:

(1) Numerous widely distributed instances have been found in which individuals who revealed no other basis for functional impairment characterized by macrocytic anemia and associated tissue changes, responded promptly to folic acid therapy, using either the synthetic or the highly

purified natural product (pteroylglutamic acid). The dietary histories of these patients have been characterized, in most cases, by an intake of foods that would provide only very small quantities of folic acid.

(2) The characteristic macrocytic anemias identified in infants, children, adult women, and adult men, most logically interpreted in terms of an etiology of folic acid deficiency, have been strikingly similar to conditions established by folic acid deficiencies in controlled animal experiments.

(3) Attempts to deplete volunteer subjects of their tissue reserves of folic acid by supplying diets adequate in other essential nutrients but low in folic acid have met with varying success. Some investigators have not found a characteristic depletion in blood, urinary, or fecal concentrations of folic acid, but in other instances there has been evidence of a slow depletion, such as would be anticipated on the basis of animal experiments and clinical observations of individuals in an uncontrolled environment. Synthesis of folic acid by microorganisms in the intestinal tract apparently accounts for a major part of the irregularity in depletion experiments. The incidence of clinical deficiencies, however, affords evidence that intestinal synthesis should not be relied upon as a source of this nutrient.

The quantitative requirement cannot be estimated closely from published evidence. Doan, *et al.* (73) observed a hematologic response from a dosage of 2 mg. of synthetic folic acid per day; Kurnick (74) observed improvement after a dosage of 2.5 mg. per day; Spies and Suarez (75) observed remission of sprue after dosages of 2.5 to 5 mg. per day; and Moore, *et al.* (76) observed a response from 2 mg. per day. Darby has observed instances of approximately maximal remission from pernicious anemia and sprue with dosages as low as 0.1 mg. per day. Comparative studies with monkeys, chickens, and turkeys, on a caloric basis, provide an indirect basis for estimating a human requirement in the range of 0.1 to 0.2 mg. per day. Many investigators suggest that estimates of requirement should be based upon studies of nutritional macrocytic anemias and directly related cases rather than upon protection from pernicious anemia. For additional references to folic acid as presumably essential to human nutrition, see References 77–85.

Vitamin C (Ascorbic Acid). Evidence in support of the figures given for vitamin C (ascorbic acid) in the Table of Recommended Dietary Allowances has been provided in an extensive literature from many research laboratories. The evidence is chiefly of the following types: (a) intake levels known to protect against the classical and less severe signs and symptoms of scurvy, for individuals ranging in age from infancy to full maturity; (b) studies of intake levels in animals and in man, relative to maintenance of specific functions such as wound healing, enzyme activity, cellular proliferation, and resistance to physiological stress; (c) tests of tissue storage at different levels of intake, with related observations of tissue injury or functional impairment; (d) studies of the quantity supplied to infants by human milk when the mother's intake of vitamin C (and other nutrients) was at a recognized satisfactory level; and (e) comparative studies in nutrition, including animals that require a vitamin C intake for protection from scurvy (guinea pigs and primates) and animals that maintain a "normal" concentration of the vitamin by tissue synthesis.

Numerous observations have been recorded to indicate the critical levels of intake that are necessary to afford protection from gross signs of scurvy, through a period of several months in infants, children, and adults. These levels (approximately one-third to one-fifth of the values given in the Table) obviously are not satisfactory in a long-time appraisal of health and may even result in clinical evidence of scurvy when the body is subjected to common forms of stress. But it is difficult to state precisely what concentration of ascorbic acid in the plasma or blood cells or what excretion level should be considered "optimal". The values given in the Table represent a conservative appraisal of all the evidence that is available, but they should not be regarded as "saturation" levels. More generous intakes result in considerably higher concentrations in the tissues.

The concentration and distribution of ascorbic acid in human tissues, from infancy to old age, is roughly comparable to the concentrations observed in experimental animals under carefully controlled conditions. A progressive depletion can be observed in guinea pigs and primates when there is a deficient intake, but when the intake is at a satisfactory level, the tissue concentrations rise approximately to those observed in animals in which the vitamin is maintained under physiological control (with no intake of vitamin C but with adequate nutrition in other respects). In guinea pigs, it is pertinent to point out that although 0.5 mg. per day will protect young growing animals against the classical signs of scurvy, abnormalities of tooth structure and slowness of wound healing remain evident until a level in the range of 3 mg. per day is reached. Maximum phosphatase activity in wounds during the course of healing is not achieved until the intake is approximately 5 mg. per day. Neither is maximum resistance against injury by bacterial toxins reached until comparable high levels are supplied.

Significant data and additional citations of the literature will be found in the recent references given, dealing primarily with maternal and infant feeding (86–90) requirements of children (91–94), requirements of adults (95–103), distribution in human tissues (104), effects upon tooth structure (105–107), and the enzyme contents of wounds during healing (108).

Vitamin D. The vitamin D requirement has been studied more extensively for infancy than for any other age period. Many of the studies have been concerned with the amount of vitamin D necessary to prevent rickets. Such studies are not particularly useful in determining a recommended allowance, since an amount greater than that which just prevents rickets produces greater calcium retention and more rapid growth. Evidence exists (109) that from 300 to 400 units daily commonly permits maximum retention of calcium in infancy when the calcium intake is satisfactory. Maximum calcium retention is associated with excellent skeletal growth and early dentition (110). Larger amounts of vitamin D do not increase calcium retention or the rates of growth and dentition (111).

A general opinion exists that prematurely born babies require more vitamin D than do babies born at term and it is a common custom to give more. No evidence exists that a larger amount is needed. Rickets to which the prematurely born infant is especially susceptible is most often due to deficiency of intake of calcium and phosphorus rather than to a

greater need for vitamin D. Few reports have been found concerning the minimum requirement of prematurely born infants for vitamin D. McQuarrie and coworkers (111a) found that the amount that would prevent rickets is not more than 540 units daily. Smaller amounts were not tried except in one case in which 300 units daily was sufficient. Glaser *et al.* (111b) found that as little as 100 units daily prevented rickets and permitted normal growth. As good calcium retention was found with 200 units daily as with 400 or 800 units. Because of the poorer utilization of fat by the prematurely born baby, the use of a water-miscible preparation of vitamin D may be considered advisable.

Evidence is good that vitamin D is needed throughout the growth period (112), but the actual requirement has not been determined accurately. It is known, however, that 400 units daily is ample for good calcium retention in children when the milk intake is appropriate (112). A few children do not require a supplement of vitamin D for good calcium retention, but the majority do. In adolescence, however, the evidence indicates that the need for vitamin D is as universal and as great as in infancy (113). The total amount required in adolescence probably is no greater than in infancy.

The need for supplemental vitamin D by vigorous adults leading a normal life seems to be minimum. For persons working at night and for nuns and others whose habits shield them from the sunlight, as well as for elderly persons, the ingestion of small amounts of vitamin D is desirable. When adults are receiving only small amounts of calcium, ingestion of vitamin D does not increase the utilization of that which is ingested, nor does vitamin D decrease the requirement for calcium (114).

During pregnancy and lactation the calcium and phosphorus requirements are greatly increased. Supplemental vitamin D increases the utilization of these elements. The optimum amount of vitamin D is not known, but retention values obtained by some investigators with high dosages of vitamin D seem no greater than those with moderate dosage. On the basis of available evidence the value of 400 units is most likely adequate.

Vitamin K. The requirement for vitamin K usually is satisfied by any good diet, except for one critical period. Special attention is required during the latter part of pregnancy and for the newborn infant. Pregnant women usually are found to have normal amounts of prothrombin in the blood, but many newborn infants have abnormally small amounts. Although little relation seems to exist between the amount of prothrombin in the blood of the mother and that of the infant at birth, the amount of vitamin K received by the mother is reflected quickly in the amount of prothrombin in the blood of her infant in utero. Seldom does the mother receive enough dietary vitamin K to prevent an important decrease in the prothrombin level of the blood of her infant during the first days after birth.

The customary concept that regulation of the amount of prothrombin is the only function of vitamin K has been brought into question. Babies have been reported in whom bleeding in the newborn period did not stop with the restoration of the prothrombin level to normal (115). Other

clinical observations (116) indicate that certain tissue lesions precede the hemorrhages in infants deficient in prothrombin and the implication exists that these lesions as well as the low prothrombin level are important in causing hemorrhage. In a study of vitamin K deficiency in chicks and infant rats (117) vascular and parenchymal lesions have been found in the brain. These lesions are of a type capable of producing brain damage or hemorrhage or both. In a study with dogs (118) a hemorrhagic condition was observed in the newborn which may have been related to vitamin K deficiency. Intracranial blood vessels were severely engorged.[2]

Although prothrombin levels can be increased within a few hours by vitamin K, it is clear that degenerative changes in vessels or brain substance cannot be corrected in a short time. While it is not yet clearly established that such lesions occur in the human fetus as a result of vitamin K deficiency, the available evidence warrants increased attention to the vitamin K intake of the mother during the latter part of pregnancy. In view of the very large number of babies with intracranial damage at birth and the possible relationship of these lesions to vitamin K deficiency, it is suggested that vitamin K be given to pregnant women during the last month of pregnancy. One milligram administered parenterally to the mother will satisfy the needs of the infant for several days, and vitamin K can be given parenterally if the physician prefers. A daily oral dose of 1 mg. will also be satisfactory. If the mother has been treated in this manner, the new born infant needs no supplement of vitamin K during the short period preceding ingestion of food.

When the vitamin K status of the mother has been unsatisfactory or is unknown at the time of labor, it is desirable that this vitamin be given to the mother before the birth of the baby or to the baby immediately after birth, preferably the former. It has been demonstrated that the prothrombin level of the baby is higher in the first days after birth if vitamin K is given to the mother before delivery than if it is given to the baby at birth. A suitable amount for the mother preceding delivery is 1 mg. administered parenterally; this amount will stabilize the prothrombin level of the infant until food is taken. A suitable amount for the infant after birth is 1 mg. for a single dose. This amount will satisfy the need until he is ingesting food. In fact, it has been shown that a single dose of 10 to 20 micrograms is adequate to cover the first five days. The daily requirement of the infant is approximately 1 microgram (119).

General Discussion[3]

The allowances for adults are given for a man of 70 kg. and a woman of 56 kg. They should be decreased or increased proportionately for smaller or larger persons within each named category. The allowances for children are given for age groups, and for boys and girls separately after 12 years

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[2] This section concerns itself with cerebral hemorrhage in infants only in relation to vitamin K deficiency. Other etiologic factors in brain hemorrhage are beyond the scope of this discussion.

[3] Some of the material of this section was presented by Russell M. Wilder in Science; 101: 285, 1945. It is used here by permission of the author and the publisher.

because from about that age the growth curves and levels of activity differ significantly.

The allowances during the growth period as shown in the table may appear to have step-like changes from one age category to another because of their being tabulated by age groups. Obviously such abrupt changes in requirement cannot occur. A man lacking one day of being 21 years of age does not have a protein requirement which decreases overnight from 100 to 70 grams. Actually the allowances are stated for the middle of the age group and for average size and activity. They are different on each side of the middle. When the allowances that are given are plotted by age, a curve is obtained that permits interpolation for ages for which no values are given. The curve of values slopes gradually from those stated for 18 years to those for adults, beginning at 21 years. For most of the nutrients listed the values at 20 years are little different from those of 21. Since size is as important as age, if not more important, at different periods of development, probably a band rather than a line on a graph represents the truth more adequately.

The allowances are for persons in health. Needs vary greatly in disease. For example, in febrile conditions an increased need usually exists for calories, thiamine, and ascorbic acid. The need for these and other constituents may be greatly altered in other diseases as well, especially those of the alimentary tract which interfere with absorption.

The values of the table are for content of foods as eaten and do not allow for losses in storage, cooking, and serving. Because such losses, especially of the water-soluble vitamins, may be extensive, provision should be made for them in planning practical dietaries. The computation of losses prior to consumption, and means of decreasing these losses, while matters of great practical importance, are beyond the scope of this bulletin. The allowances are meant, however, to provide for possible incomplete availability or absorption of certain nutrients such as iron and calcium.

The allowances are intended to serve as a guide for planning an adequate diet for every normal person of the population and not merely for the average member of the group categories. Experience has shown that the biological normal consists of a range of values. An allowance based on the need of the average of a group would be greater than the need of many and less than the need of many others. Many normal adult males require only 2,200 Calories or less and many can subsist in health with half the stated protein allowance. Many children need no supplemental vitamin D, while others require the amount stated. In order to meet the needs of the whole population it is necessary to satisfy the requirements of those with less efficient usage. Because the allowances take into consideration the requirements of those of the upper level of the normal range of requirement, they allow a factor of safety for persons who have an average or less than average requirement. In most categories this factor of safety for the average person is estimated to be approximately 30 percent; nevertheless, it is probable that for many normal persons the allowances cover only the amounts needed for maintenance. Inasmuch as some persons who receive less than the recommended allowance of one or another nutrient may remain in health through long periods, it becomes apparent that these

allowances are not to be used as the sole criteria for judging the state of nutrition of any population. Persons whose consumption equals or exceeds the goals are presumed to be adequately nourished in accordance with the basis for setting up the allowances. Not all people who fail to reach the goals, however, are necessarily malnourished.

In addition to meeting the immediate needs of normal persons with relatively low efficiency, the allowances are expected to cover for the average person any differences that might exist between short-time need and that for the life span, though information is lacking that would permit stating with accuracy the amounts of the various nutrients more suitable for the whole life span. The various studies that have been used as a basis for judgment as to minimum requirements were for periods not longer than 6 to 9 months, not more than 1 percent of the life span. Studies with animals have indicated that amounts of some nutrients sufficient to provide health for short portions of the life span may be inadequate to maintain good health for the life span as a whole.

While the allowances do not provide a basis for judging nutritional status of populations, they nevertheless serve as a guide for feeding population groups. When the tables are used to estimate the per caput needs of population groups and the agricultural production required to supply such groups, the allowances should be weighted by the composition of the population according to the categories and ages.

It seems desirable to present as a goal the nutritional welfare of the majority of persons, without limitation to those with average requirement or less. Few persons know whether their individual needs are greater or less than the average and no easy method exists for determining such status. If the total food supply for a population is insufficient to meet these recommendations, the remaining existing need must be recognized frankly despite the embarrassment that may ensue. It becomes necessary to distinguish between standards based on good nutrition for all and more immediate consumption goals based on practical possibilities.

Diet Plans that Meet the Recommended Dietary Allowances

In using the recommended allowances, it is to be emphasized that the amounts of various nutrients, with the exception of vitamin D, can be obtained through a good diet of common foods. It is fortunate that excellent nutrition can be provided by many different combinations of foods. However, even though this is true, foods selected with care will give greater returns in health for money spent. The safest way to insure that the allowances are met is to include in the diet every day certain foods in specified amounts.

The dietary pattern given in the National Food Guide or "Basic 7" (120) is a general guide for selecting an adequate diet at home or when eating out. It classifies most foods into seven groups based on nutritive content and use in meals. The approximate number of average-sized servings that will furnish a diet adequate in protein, minerals, and vitamins has been suggested for each of the seven groups. If more food is needed to meet individual calorie needs, larger quantities can be selected from the seven groups or from a separate list of foods valuable chiefly as sources of

energy. At best any guide to food selection suggesting numbers of servings of various kinds of foods is very rough. Except for a few foods—milk, for example—there is no general agreement as to what constitutes an average serving. Obviously the number of servings needed depends greatly on their size.

Three types of menus are given on pages 26–27 to illustrate how adequate diets can be developed in line with the Basic-7 plan using different combinations and quantities of food. The amounts of foods suggested for preparing these menus will provide the dietary allowances recommended for a "physically active" man with some margin allowed for cooking losses. On the basis of nutrient equivalence, other foods, or combinations of foods, can be used to the same end.

Menu I represents a meal pattern followed in many parts of the country. It includes 2 cups of milk, one of which is used as a beverage, and also some additional milk in other forms, such as cheese, evaporated milk, and baked goods.

Menu II features the important contribution that leafy, green, and yellow vegetables can make to a diet. The smaller quantity of milk in these meals is possible only because of the relatively large serving of turnip greens (or kale or collards) which are among the best non-milk sources of calcium. These foods also can be excellent sources of ascorbic acid if suitable cooking methods are used.

Menu III suggests a sample of food combinations often found in the Southwest region of the United States. With this particular assortment of foods it is necessary to include about 3 cups of milk to provide the recommended amounts of calcium. No allowance has been made for any calcium which may be absorbed during the preparation of cornmeal for tortillas. Little information is available on the calcium content of tortillas made in this country. In these calculations it has been assumed that they are made of enriched wheat flour or enriched cornmeal; otherwise this day's meals would be low in thiamine.

Quantity guides for the selection of an adequate diet at different food cost levels have been published by various national, state and local groups concerned with the health and welfare of individuals and families. For example the plans (121) of the Bureau of Human Nutrition and Home Economics suggest quantities of food for a week that will furnish the recommended daily dietary allowances for each of the seventeen categories. These plans suggest quantities for eleven major food groups from which individual items for market orders and menus may be chosen to suit the family's preferences. In estimating the nutritive value and cost in each of these food plans, it was assumed that food selections follow the patterns indicated by national dietary studies.

In any food plan giving quantities of food groups, as well as in the "Basic 7" plan, consistently poor choices of foods can result in inadequate diets. Even though foods grouped together are similar in nutritive value, there is great variability among individual items. For example, the vitamin A value of the dark green leaves as spinach, kale, and turnip greens is probably 10 to 12 times greater than that of green non-leafy vegetables like asparagus, peas, snap beans, and green peppers, which are in the same

THREE TYPES OF MENUS WHICH WILL FURNISH RECOMMENDED

	Menu I
Breakfast	Orange juice Cooked cereal—milk Eggs Toast—Butter or fortified margarine Beverage
Lunch or supper	Baked macaroni and tomatoes Green beans Rolls—Butter or fortified margarine Fruit in season Milk
Dinner	Broiled chopped steak Creamed potatoes—carrots Head lettuce—French dressing Bread—Butter or fortified margarine Apple pie and cheese Beverage

QUANTITIES OF FOODS REQUIRED

The Basic-7 food groups	Listed in Menu I
1. *Leafy, green, and yellow vegetables* 1 or more servings	½ pound green beans 3 or 4 small carrots
2. *Citrus fruit, tomatoes, raw cabbage* 1 or more servings	6 ounces orange juice ½ cup canned tomatoes
3. *Potatoes and other vegetables and fruits* 2 or more servings	1 large potato ¼ small head lettuce ½ to 1 cup fresh or canned fruit 1 medium apple
4. *Milk, cheese, ice cream* Children—3 to 4 cups of milk Adults—2 or more cups	2 cups whole milk 2 tbsp. evaporated milk 1 ounce Cheddar cheese
5. *Meat, poultry, fish, eggs, dried peas, beans* 1 to 2 servings	2 eggs ¼ pound chopped beef
6. *Bread, flour, cereals, whole-grain, enriched, or restored* Everyday	1 cup cooked cereal 4 slices bread 2 rolls 1 ounce flour
7. *Butter and fortified margarine* Some daily	1 to 2 ounces or about 5 pats
Additional energy-yielding foods[2]	1½ ounces macaroni 2 tbsp. French dressing 1½ tbsp. shortening 2 to 3 tbsp. sugar

[1] All quantities are based on raw foods except where otherwise indicated.
[2] Additional foods used in estimating the nutritive value of the above meals.

DIETARY ALLOWANCES FOR A "PHYSICALLY ACTIVE MAN"

Menu II	Menu III
Tomato juice Ready-to-eat cereal—milk Eggs Hot biscuits Butter or fortified margarine—jelly Beverage	Banana on ready-to-eat cereal Milk Toast—Butter or fortified margarine Beverage
Baked sweetpotato Turnip greens or collards Sliced onions with vinegar Corn bread or muffins Butter or fortified margarine—molasses Beverage	Chick pea soup Tortillas Orange Cocoa or Chocolate
Fried fish Hominy grits—cole slaw Bread—Butter or fortified margarine Stewed prunes or fruit in season Cookies Beverage	Chili rellenos (Stuffed green peppers) Mexican rice Raw vegetable salad (Cabbage, carrot, green pepper, French dressing) Tortillas Fruit gelatin Milk

FOR THE THREE MENU TYPES[1]

Basic-7 groupings

Menu II	Menu III
1 cup cooked turnip greens or collards	4 to 5 green chili pods 1 medium carrot
6 ounces tomato juice 1 cup shredded cabbage	1 small orange ½ cup canned tomatoes 1 cup shredded cabbage
1 large sweetpotato 1 medium onion 4 or 5 medium prunes or fruit in season	2 slices onion 1 medium banana ⅓ cup diced apple, pear, peach, melon, berries, etc.
1 cup whole milk 3 tbsp. evaporated milk	2½ to 3 cups whole milk 2 tbsp. evaporated milk
1 or 2 eggs ⅓ to ½ pound fish, dressed weight	1 egg ¼ pound stew beef 2 ounces chick peas
1 ounce ready-to-eat cereal 2 slices bread ½ cup white corn meal ¼ cup hominy grits 2½ ounces flour	1 ounce ready-to-eat cereal 2 slices bread 5 ounces flour or corn meal
1 to 2 ounces or about 5 pats	1 ounce or about 3 pats
3 cookies 1 tbsp. salad dressing 3 tbsp. shortening 1 ounce salt pork 1 tbsp. sugar 1 tbsp. jelly or jam 2 tbsp. molasses	1½ ounces rice 2 tbsp. French dressing 1½ tbsp. shortening ½ ounce chocolate 2 tbsp. sugar ¼ 3-ounce package gelatin dessert powder

group. Diets of persons who regularly choose from this group only such foods as cabbage, peas and snap beans, might easily be short in vitamin A value unless larger-than-average servings of these and other sources of vitamin A are taken.

Some foods are important because of their unique nutritional contribution and cannot be replaced easily in the diet. Milk is an outstanding source of calcium, riboflavin, and many other nutrients. Without milk or its products it is almost impossible to meet the daily calcium needs from ordinary foods. In 1947, 75 percent of all the calcium, and nearly half of the riboflavin in our national food supply was furnished by milk and milk products. No other food group supplies more than 4 per cent of the calcium. Citrus fruits and tomatoes are important as a dependable source of vitamin C. Although in the food supply as it enters the kitchen (122), leafy, green, and yellow vegetables furnish almost as much vitamin C as do citrus fruit and tomatoes, the losses that occur in preparing vegetables for eating are considerable. On the other hand, the citrus fruit and tomatoes are eaten fresh extensively and the original vitamin C is well retained under suitable conditions of processing and storing.

For some population groups such as adolescent girls and pregnant and nursing women, it is essential to select nutritionally high quality foods regularly or it will be extremely difficult to meet the needs without an excess of calories. Even with the daily quantities suggested for enriched, fortified, or restored cereal products and for leafy, green, and yellow vegetables, it is difficult to supply these special group needs without often including such iron- and vitamin-rich foods as liver.

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The National Research Council

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The Council was established at the request of the President of the United States, by the National Academy of Sciences, under its Congressional charter to coordinate the research facilities of the country for work on military problems involving scientific knowledge. In 1918, by Executive Order, it was reorganized as a permanent body for the general encouragement of scientific research.